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ABSTRACT

In this paper, an information processing model of social systems is developed with particular concern for large complex organizations. In explicating the sixteen assumptions and propositions of the model, the literature on environmental uncertainty, interorganizational communication, technology, and their effects on internal organizational processes is reviewed. A multiple regression analysis of data from a large eastern financial institution strongly supports four propositions: (1) the greater the zone size, the greater the complexity of the internal communication network of the system, (2) the greater the zone integration, the less the complexity of the internal communication network of the system, (3) the greater the system openness, the greater the complexity of the internal communication network of the system, and (4) the greater the system size, the less the complexity of the internal communication network of the system. (Author/RB)

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An Information Processing Model of Organizations: A Focus on Environmental Uncertainty and Communication Network Structuring[1]

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ABSTRACT

When organizations are viewed as information processors, environmental variables become highly important. In this paper, an information processing model of social systems is developed with particular concern for large complex organizations. In explicating the sixteen assumptions and propositions of the model, the literature on environmental uncertainty, inter-organizational communication, technology and their effects on internal organizational processes is reviewed. Many of the propositions in the model develop relationships among environmental variables and the complexity of communication networks within systems.

A secondary analysis of data from a large eastern financial institution is used to provide a preliminary test of the following propositions derived from the model: 1) The greater the zone size, the greater the complexity of the internal communication network of the system, (2) the greater the zone integration, the less the complexity of the internal communication network of the system, (3) the greater the system openness, the greater the complexity of the internal communication network of the system, and (4) the greater the system size, the less the complexity of the internal communication network of the system.

A communication network analysis yields 37 subsystems which have linkages to other subsystems. These data provide the basis for preliminary evidence regarding the validity of these propositions. A multiple regression yields strong support for propositions 2, 3, and 4, and the set of independent variables drawn from the model explains 70% of the variance in the internal complexity of the communication network structures of these systems.

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Overview

Traditionally, organizational theory and research has focussed almost exclusively on intra-organizational processes and characteristics. The external environmental factors which might influence these processes were largely ignored. This shortcoming of theory regarding organizational processes is now beginning to dissipate rapidly. Within the last two decades, the study of organizations has first seen a conceptual treatment of the effects of environmental factors on intra-organizational processes, and then a trend toward an empirical testing of some of the proposed relationships among environmental and intra-organizational processes.

Two major factors may help explain these trends and place them into perspective. A primary consideration has been the realization that the classical, neo-classical, and human relations theories,[2] which generally posit one best way to organize, have often not survived the tests of empirical validation. This has led to the "contingency theory" approach to developing theories of organizational behavior.[3]

A second important impact upon attention to the environment has been the development and widespread use of "systems theories" of organisms and organizations.[4] Core principles regarding "open systems" highlight the environmental influence. It might also be suggested that heightened awareness of the importance of maintaining the "physical" environment in our society has enabled a clearer cultural conception of environment and its importance in other contexts.

In this paper we will highlight three major categories of environmental variables which have been explored in various ways in the literature. Two

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are aspects of the external organizational environment: environmental uncertainty and inter-organizational communication. The third is part of the internal environment: technological uncertainty. We will explore some possible relationships among these variables and the complexity and uncertainty of communication networks within the organization.[5]

In the next section of this paper, we will explicate a model of organizations as information processors. Many of the assumptions made and the propositions which are developed may apply to systems in general. However, our specific focus is on large complex organizations. Figure 1 provides a summarization of the major components of the model.

Insert Figure 1 About Here

The Model

1. Organizations create and process varying amounts of uncertainty in their environment.

Viewing an organization as a processor of information immediately suggests that environment is of primary import. To create and process information, an organization must interact within an environment. If the organization were to stand alone as an isolated "closed system", no information inputs would be possible. Hence, when we view organizations as communication scholars, focussing on their information transducing processes, we must account for the organizational environment with which the organization interacts in processing information.

We view the definition of an organizational environment from a "phenomenological" perspective. As such, the organization does not "discover" an environment with which to interact. Environment is not an "objective"

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and independent component, although the tendency has been to reify environment along these lines. It is more useful to say that the members of an organization enact a composite environment which is subject to rapid change.[6]

The members of an organization create an environment by projecting or imposing a conceptual organizing structure onto a space/time context. For environment to "exist" a perceived space containing perceptual units which form various relationships among each other must be developed.[7]

The construct of boundary is important to any discussion of environment/system interaction. We may define the boundary of a system which separates the internal environment from the external environment, to be the point at which the organization has more than 50% perceived control over the environment, and therefore, more than 50% of its communication with components within this boundary.

While the mere concern with organizational/environmental interactions has heuristic value, for empirical value to develop, there must be a way to develop a conceptual and operational framework for more precise theoretic manipulations regarding these processes.

To meet this objective, a way to conceptualize variation in organization environment is in terms of environmental uncertainty. The relationship of uncertainty to information has been explicated in the now classic work of Shannon and Weaver.[8] Information is the reduction of uncertainty. Therefore, uncertainty is potential information. Uncertainty has been defined in general terms as a function of the number of alternatives for the occurrence of an event or perceived outcome and the relative probabilities of these alternatives. As the number of alternatives increases, and their occurrence becomes more equiprobable, uncertainty increases. Thus, when

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this increased uncertainty is reduced, there is increased information generated in the processing of uncertainty.

The literature regarding environmental uncertainty has its origins in the work of Knight[9], who early in this century first explicated the relationships between environmental uncertainty and organizational processes. The specific focus of this work was organizational decision-making regarding risk and profit as a function of the uncertainty of the environment. Since that time, there has been a growing number of organizational theorists who discuss various ways to conceptualize the uncertainty of environments and their relationships to various organizational processes.[10] In general, these perspectives coalesce around the notion that environmental uncertainty is a function of the degree of predictability of environmentally related phenomena.

The discussion and explication regarding environmental uncertainty in the organizational literature has tended to be relatively concrete in nature. Nearly all have been concerned with relationships to decision-making processes. The various conceptions of environmental uncertainty for organizations can be summarized as follows:

(1) the lack of information regarding the environmental factors associated with a given decision-making situation,

(2) not knowing the outcome of a specific decision in terms of how much the organization would lose if the decision were incorrect, and

(3) inability to assign probabilities with any degree of confidence with regard to how environmental factors are going to affect the success or failure of the decision unit in performing its function.[11]

However, in addition to uncertainty which directly impacts upon organizational decision-making, uncertainties can be conceptualized which are more general and wide-ranging in nature, but which are likely to have a major influence on the manner in which organizations function. A useful conception

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of these more general uncertainties may be input uncertainties and output uncertainties.

Input and output uncertainties arise from a variety of sources. Two broad sub-categories of input/output uncertainties are channel uncertainties and content uncertainties. Uncertainty arises in the relative use or activation of channels for information flow to and from the environment. The more channels through which messages can flow and the more equiprobable the use of these channels, the higher the channel uncertainty.[12]

Uncertainty also arises from the amount of variance occurring in the kinds of content of messages flowing between an organization and its environment. There can be a range of alternatives for the organizational structure of messages, as well as the meaning attributed to the symbols by the organization. As the number of alternative messages, structures, or formats increases, the number of alternative meaning attributions increases, and the probability of the occurrence of these alternatives becomes more equal, the higher the uncertainty.

Messages are only a subset of the matter and energy exchanged between organizations and their environment; they have symbolic content.[13] Non-symbolic matter/energy such as the resources which an organization requires, provide a basis for environmental uncertainty. Uncertainties may arise from such things as the number and relative probabilities of alternative resource inputs to, or outputs from, the organization; the number of alternative sources for, and receivers of these resources; or the variation in input and output flow of these resources, etc.

Environmental uncertainty is then a highly multi-dimensional construct.[14] In developing theories involving this construct, very specific kinds of uncertainty can be examined with respect to very specific kinds of intra-organizational processes. However, because of the relative nature of

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uncertainty and its multi-dimensionality, the relationships among environmental uncertainty and intra- and inter-organizational processes can be examined at varying levels of abstraction. In this paper, we are attempting to develop a model of organizations as information processors which is relatively wide in scope. Therefore, in the interests of space maximization and comprehensibility, we will explicate this preliminary model at a relatively high level of abstraction. Hence, we will be concerned with environmental uncertainty in its most general terms. Further writings will explicate the respective components of model in more detail at another time.

2. The greater the environmental uncertainty, the more complex the inter-organizational communication networks.

An organizational environment is not created in isolation from other organizations. The nature of the projected organizing structure is influenced by the exchange of information among a set of organizations. There are socialization influences occurring through the processes of inter-organizational communication which set the parameters for environmental projections.[15]

These socialization processes lead to the occurrence of some degree of overlap in the projection of conceptual organizing structures. Organizations then come to share to varying degrees the organizing structures which provide the bases for communication among them and therefore share an environment. It is a relatively well accepted proposition that the degree to which communication between individuals is effective will be a function of the degree to which there is overlap in the conceptual structures, ways of perceiving, "world view", past experiences, etc., of the participants.[16] In addition, research has shown that the degree of attitudinal/perceptual/behavioral similarity predicts the simple amount of communication between people with considerable precision.

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It appears reasonable to propose that this hypothesis is capable of cross-level generalization--a core methodological assumption of systems theories of organismic behaviors.[17] Therefore, the degree of overlap in the conceptual space and inter-conception relationships among organizations will be associated with the occurrence and effectiveness of communication among them.

For an organization to function as an "open system" and hold in check or reverse the movement toward increased entropy or disorganization which is predicted from the Second Law of Thermodynamics,[18] the system must exchange materials and information with elements of its projected environment--organizations, groups, dyads, individuals, etc. This process can occur only to the extent that organizations develop relationships through the establishment and maintenance of communication networks among them.[19] Through the development of these inter-organizational communication networks, a shared consensual domain of concepts and relationships comes about, within which these organizations participate.[20] Consensus among organizations is a way to describe these processes of overlapping and socialization discussed above. This approach is useful in integrating phenomenological, social/phenomenological, and sociological perspectives on human behavior into a coherent paradigm. The prime implication of this integrated perspective is a focus on rules and rule-governed experiential phenomena.[21]

An organization is able to operate effectively only when the amount of environmental uncertainty is appropriate to its ability to process information (we will elaborate on this proposition shortly). Organizations, then, must create an environment with less than maximal possible uncertainty. To accomplish the establishment and maintenance of an environment which approximates to some degree the optimal amount of uncertainty required for effectiveness, organizations must reduce the number of alternatives and probabilities

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of alternatives perceived to be relevant to their operations on a wide range of dimensions. This restriction upon the environment may be accomplished through the generation of rules within the inter-organization domain which establish limits upon the number and frequency of occurrence of alternatives which are permitted or required to occur in specified circumstances or environmental subcontexts.

As we discussed previously, the creation of consensually validated rules requires the interaction of a set of organized entities. As the environment becomes excessively uncertain or the level of certainty required by organizations must be relatively high, more complex rule structures will develop. This will coincide with the development of correspondingly complex inter-organizational communication networks through which these rules take structure and content.

3. Greater density of organizations per unit of resource space produces greater environmental uncertainty.

From an economic perspective, the resource space of organizations has a limited supply. As demand for these resources increases, competition for limited resources will lead to greater uncertainty with respect to the availability and stability of resource inputs for organizational processing.[22]

On the output end, greater density may also lead to an over supply of organizational outputs. The competition for the distribution and exchange of these outputs will lead to conditions of uncertainty for participant organizations.

Environmental uncertainty can also be examined with respect to the structural characteristics of the organization-centered inter-organizational communication networks. Two primary structural variables are zone size and zone integration.[23] Zone size increases as the number of different entities

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to which a particular organization is linked, through message exchanges, increases. Another term which is very similar, but which has less clarity with respect to the structural pattern of inter-organizational networks, is system openness.[24] Environmental uncertainty will increase as the number of organizations to which an organization is linked increases. This will be a function of increased input channel uncertainty. This notion can be summarized in the following proposition:

4. Greater zone size produces greater environmental uncertainty for a particular organization.

Zone integration will also contribute to the uncertainty of messages flowing into an organization.[25] The extent to which the entities to which a particular organization are linked to each other through the exchange of messages defines the level of zone integration--higher interlinkage yielding higher zone integration. Higher zone integration for an organization will produce reduced uncertainty in the messages flowing into the organization, since the organizations in the set exchange a high number of messages with each other. This suggests the following proposition:

5. Greater zone integration produces less environmental uncertainty for a particular organization.

All organizations are not able to process the same amounts of environmental uncertainty:[26]

6. Organizations vary in the amount of information which can be effectively processed in the environment.

A critical aspect of the internal environment of organizations is the technological context for task performance. Many have proposed, beginning at the turn of the century,[27] that the nature of an organization's technology will be associated with the manner in which the social system is organized.

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The question of the relationship between technology and social structure becomes increasingly important to answer as the rate of change, complexity, and sophistication of technology accelerates in industrialized nations. Of particular relevance to scientists of communication phenomena are the relationships between increasingly sophisticated communication technology (computerized information processing systems, audio-interconnect systems, facsimile transmission, etc.) and the internal processes of organizations. In retrospect, we may observe that the growth of organizations which primarily process information rather than material/energy has been tremendous. As a result, the communication technology context is likely to be associated with the manner in which information is processed within an organization and the social relationships among subsystems of the organization and the relations of the organization to other organizations in its environment.

All organizations can be considered to have a technology.[28] Technology is the processing of materials and/or information as the organization functions within its environment. As such, technology is a very broad construct and considerably more abstract than the standard, non-scientific use of the concept.

Technology has been examined in an empirical context by a number of researchers.[29] The primary variables which have been related to technology in the area of organizational theory are variables which quantify the structural complexity of the system (these relationships will be discussed shortly). The original work regarding technology was conducted by Woodward,[30] who examined technology in the context of the types of manufacturing processes used in various industries in Southern England. Since this research was first reported, a number of researchers have gone beyond this crude conceptualization and operationalization of technology and have generally explicated

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technology in terms of the degreee of control or certainty in task operations within the organization.[31] The greater the certainty of task operations, the greater is the extent to which the technology is "advanced". From this perspective, then, technology is not necessarily bound by "hardware".

The technology of organizations will have important relationships to the uncertainty of organizational environments. The certainty of technology will be a function of the certainty of the environment. The direction of the relationships is likely to be non-recursive. Increases in environmental uncertainty will produce increases in the technological uncertainty of the organization, which will in turn produce increases in environmental uncertainty. These components of the relationship, however, are not equally strong. Technological certainty requirements are likely to heavily constrain the amount of fluctuation in environmental uncertainty which the organization is able to withstand. Therefore for simplicity, we will state the proposition in a unidirectional fashion:

7. Greater requirements for technological certainty produce less environmental uncertainty for a particular organization.

To maintain a level of certainty in task operations, the organization must operate in an input/output environment which is correspondingly certain. Otherwise, the technology cannot operate effectively since it is either under-utilized or over-utilized. Thompson,[32] in discussing this relationship, elaborates on the manner in which organizations will alter the input/output uncertainty of the environment by various buffering devices. One example of input buffering is the accumulation of large reserves of input materials in order to maintain a steady processing throughput in the face of fluctuating availability of resources. Regarding output buffering, the organization may accumulate large warehouse inventories or have special marketing strategies

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in order to mediate and reduce the impact of fluctuations in the distribution or exchange of materials and/or information. This suggests the following proposition:

8. Greater requirements for technological certainty by an organization produces greater control over the environment in reducing environmental uncertainty.

As we pointed out above, the organization must balance environmental uncertainty with technological certainty in order to function effectively. In the next proposition we discuss this process in more detail:

9. Greater deviation of environmental uncertainty above or below a range of optimal uncertainty produces greater alteration of uncertainty from components in the environment.

When systems experience information underload or overload,[33] stress develops. Stress may result from the reduction of information processing activity to the extent that the under utilized communication network linkages dissolve and a more simplified structure develops. Stress then occurs as the communication network can no longer process the nature and amount of information necessary to achieve environmental and internal control component "referent" expectations for system performance.[34]

With the opposite type of imbalance--overload--excess uncertainty may lead to a level of information processing which exceeds the channel capacities and transduction[35] capabilities of nodes in the communication network. Information overload has been found to lead to confusional states in human-based components and subsequent malfunctioning through the development and use of inappropriate rule structures for information processing.[36]

Organizations react to stress by altering the environmental uncertainty or the internal technological uncertainty and communication network uncertainty. Stimulated by the recognition of stress, either through production

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reports, or human factor indicators which are either validated through subjective recognition, and/or, external system intervention (perhaps including survey data gathering and analyses), the organization initiates organizational change and development programs[37] to bring environmental uncertainty and technological and communication network uncertainty into balance. The following proposition follows from preceding portions of the model:

10. Greater requirements for technological certainty produce more highly integrated organizational zones and more highly interconnected inter-organizational networks.

We discussed earlier the proposition that the reduction of environmental uncertainty will be accomplished through the establishment and maintenance of inter-organizational communication networks. If the entities to which a particular organization are connected are highly interconnected, then there may be a greater likelihood that the messages which flow through this inter-organizational network produce less uncertainty. All of the components are exchanging information under more predictable rules, greater consensus is likely to be operative, and the result is likely to be a convergence of conceptual domains through the development of large inertial masses for conceptions within the domain.[38]

Empirical research investigating the relationship between environmental uncertainty and inter-organization communication network integration and the complexity of the structure within the organization has generally shown that the more uncertain the environment of the organization or the less interconnected the organization set of which the particular organization is a member, the greater the decentralization of decision-making, the greater the participation of components in decision making, the greater the differentiation into functional groups, the less interconnected and integrated the groups, the greater the spans of control, the fewer the hierarchical levels, and the less procedural formalization.[39]

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Another variable related to the degree of environmental uncertainty and technological uncertainty is the future time orientation of the organization.[40] Organizations which receive a "rich knowledge" of the immediate environment are likely to have a shortened "time horizon". The certainty of the present environment is not likely to stimulate planning for adaptation to changing future environments. The lack of planning and shortened time horizon may increase the likelihood that long-term ineffectiveness may plague the organization. In addition, organizational ineffectiveness is more likely to occur the greater the extent to which there is a change from the present environment to the future environment. The reasoning is generally supported by empirical research which deals with these variables. The following proposition summarizes this aspect of the model:

11. Greater immediate environmental uncertainty produces a longer organizational future time orientation.

The time lag between the awareness of organizational stress and the completion of a successful organizational development program which results in an effective adaptation to the environment will be influenced in part by the degree of control which the organization perceives itself to have over the environment,[41] based on its past interactions with it. The following proposition specifies this relationship:

12. The greater the technological certainty required by an organization, or the greater the perceived control over the environment, the greater acceleration and velocity of organizational change.

Organizations with greater perceived control over the environment will implement change programs more quickly. This may be due to the learning from previous environment/organization interactions that more rapid adaptation is associated with reduced costs for continued organizational functioning.

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Since all of Western "rationality" in general[42] and principles of capitalism in particular suggest a basic goal of maximization of organismically-centered resources, then increased motivation should be provided for altering environmental and/or intra-organizational uncertainty. The outcomes of this kind of organizational action will be a more adapted system and level of information processing.[43]

The variable of organizational size has been important in the structuralist school of organizational theory.[44] Size is thought to have a large impact on the degree of "bureaucratization" of organizations.[45]

In order to develop precise propositions including size as a variable, size must be measured effectively. Essential to this operation is the necessity of defining the manner in which the boundaries of organizations can be delineated. If this is not done, there is no way to unambiguously determine which systemic components are within the organization and which are external and part of the environment.

As we stated earlier, we may define the boundary of a system which separates the internal environment from the external environment, to be the point at which the organization has more than 50% perceived control over the environment, and therefore more than 50% of its communication with components within this boundary. Since different organizations are likely to also perceive control over the same components over which other organizations perceive control, then boundary conflict regions will develop.[46] Perhaps "demilitarized" zones will be negotiated after continued periods of maximum boundary uncertainty and conflict.

Boundary conflict leads organizations to the dynamic shifting and alteration of boundary demarcation. Therefore, over time, some organizations will increase in size, while others decrease (at least until the environmental resource base is expanded). This suggests the following proposition:

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13. Greater requirements for technological certainty produces an increase in the size of the organization, and a more rapid size increase under uncertainty discrepancy conditions.

In addition to the expansion of a single organization in size, another process may occur as a result of high needs for technological certainty. When an interconnected set of distinct organizations all contribute to a low average required level of environmental uncertainty, a new control component organization may be created at a higher level, thus expanding the hierarchy upward. This control component, coupled with the organizations in the set over which greater than 50% of control is exercised, will result in the formation of a new meta-organization. This, then, becomes an organization with much larger size and environmental scope. These ideas can be summarized in the following proposition:

14. Greater average required technological certainty among a set of organizations produces greater development of meta-organizational restructuring.

The major dependent variable which we would like to focus upon in this paper is the complexity of the intra-organizational communication network. The communication network[47] of an organization is the structure through which messages flow in the processing of information from the environment. This network may consist of a set of nodes and information exchange relationships among them at varying levels of abstraction: individuals, dyads, groups, and groups of groups. In this model the network is defined with individuals as the primary nodes upon which the communication network is based. The relationships among nodes are determined by the exchange of messages. The frequency and duration of message exchange provides an indicator of the strength of each dyadic relationship.[48]

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Communication network complexity or uncertainty[49] may be conceptualized on the following dimensions. The more complex or uncertain the communication network:

1) the greater the number of groups in the network (differentiation),[50]
2) the lower degree of interconnection among groups (integration),
3) the higher degree of connectivity within groups,
4) the greater the number of bridges relative to the total number of links between groups,
5) the fewer the number of status levels contained within the network, relative to the number of nodes in the network,
6) the more rapidly changing the network structure
7) the greater the balance between initiation and reception of messages by nodes in the network.

The degree of complexity of the intra-organizational communication network is a function of the amount of environmental uncertainty and the degree of technological uncertainty. First, the following proposition will be discussed:

15. The greater the environmental uncertainty, the greater the complexity of the intra-organizational communication network.

The second Law of Thermodynamics suggests that in closed systems energy flows from areas of higher energy to areas of lower energy, until a balance of energy is reached. However, if there is a restriction upon the amount of energy which can be input into a system, then this energy flow will stop short of equalization. Katzman[51] has drawn the analogy between energy and information in terms of this principle of thermodynamics, in developing a "social entropy model" of information flow in social systems. This suggests that information and uncertainty will flow from areas of higher uncertainty to areas of lower uncertainty. Following this reasoning, the greater the amount of uncertainty in the organizational environment, the greater the uncertainty or complexity of the intra-organizational communication network.

Research has generally shown it to be the case that in human-based systems the prolonged processing of uncertainty at a particular level will

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lead to the development and maintenance of a corresponding level of complexity of the information processing network.[52] However, in large organizations, the amount of certainty required by the technology, which may be limited by the nature of the materials and/or information, or the output specifications for "products", will place constraints upon the alteration and fluctuation in the complexity of the communication network. To have a given level of technological uncertainty, the organization must have a corresponding level of complexity in the communication network. The maintenance of a level of technological control is determined by the extent to which control exists over information flow within the organization. An organization cannot have a high degree of technological control or certainty, without a high level of control over information flow. Control over information flow comes about through the development of hierarchy and status orders which place restrictions upon alternative behaviors for organizational members. This reasoning suggests the following proposition:

16. The greater the technological certainty, the less the complexity of the intra-organizational communication network.

A considerable amount of empirical research supports this proposition. The findings of this research generally are that as technological certainty increases, there are fewer functional groups, greater numbers of supervisors relative to the number of subordinates, greater numbers of hierarchical levels, more formalized organizational rules, and more centralized decision-making.[53] These factors are consistent with the indicators of communication network complexity developed earlier in the paper.

Extreme certainty in internal processes can increase only up to a point. At a point when internal processes become so certain that no change over time occurs, there can be no relationships among components. For information to flow within systems there must be uncertainty discrepancies within components.

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We have now explicated a model of organizations as processors of information. The sixteen assumptions and propositions we have developed are not intended to be inclusive of all phenomena which might be conceptualized in these terms. Our objective has been to lay out the model at a level of abstraction which would indicate the basic thrust we are attempting to achieve without being unduly complex at this point.

In this next section we will describe a secondary analysis of data which may be used to test some propositions derived from the model. It is intended that this be more exploratory in nature than rigorous hypothesis testing. This preliminary work will be useful in suggesting directions for future research which is designed directly for specific empirical validation of hypotheses.

The Research

The model we have explicated has many propositions within it that are cross-system-level in scope. We will test some of these propositions at a group level of analysis within an on-going organization. Since the gathering of a large enough sample of organizations to test portions of the model at a macro-level of analysis was not possible, subsystems of a larger system will constitute the sample. The larger organization then becomes the relevant potential environment for these units. We will test the following propositions drawn from the model[54] through a secondary analysis of data:

1) The greater the zone size, the greater the complexity of the internal communication network of the system.

2) The greater the zone integration, the less the complexity of the internal communication network of the system.

3) The greater the system openness, the greater the complexity of the internal communication network of the system.

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4) The larger the size of the system, the less the complexity of the internal communication network of the system.

Data were gathered in one large division of an eastern financial institution. The task activity of the system involves the processing of transactions in stocks and bonds. The entire system was censused, yielding an 'n' of 963.

The instrument upon which this analysis is based was administered in group interviews along with a larger packet of instruments. Respondents were assured that their responses would remain anonymous and furthermore, the results of the analysis were not returned to management or any other members of the organization.

A paper and pencil questionnaire was used to elicit responses suitable for a communication network analysis. Respondents listed what other members of the division they communicated with at what average frequencies. The content categories of production, maintenance, and innovation were used. Respondents checked a box indicating how often they typically communicated with each person nominated: less than once or twice a month, once or twice a month, once or twice a week, once a day, or several times a day.

These ordinal frequency levels were converted to approximate interval scales to yield more precise measurement of the network. A baseline of 1 was used to indicate a frequency level of once per month. Only frequencies of once or twice a week and more often were used in the analysis. Once or twice a week became coded as 6, once a day as 20 (twenty working days in a month), and several times a day as 50.

The three content categories were combined by adding the frequency values for each category to yield a summary measure of the amount of communication and the strength of relationship between all pairs of nodes in the system.

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These data were input to the "NEGOPY" network analysis program which is a computerized algorithm for defining the communication network structure of systems of up to 5,000 nodes in size.[55] The analyses using only reciprocated data result in the definition of 56 groups in the system.

Operational Definitions

The complexity of the communication network structures, or connectedness of the systems is calculated by determining the total number of linkages among all members of the system, and dividing by the maximum possible number of linkages:[56]

$$C = \frac{\text{\# actual links}}{n\,(n-1)/2}$$

where n is the number of persons in the system.

As the communication network of the system becomes more interconnected, it becomes more complex.

Zonal size is measured by calculating the number of systems to which a particular system is linked through bridge, liaison, and other two-step linkers. The larger the number of groups linked to a particular group, the larger is the zonal size of the group.

Zonal integration is measured by calculating the entropy of the structure among the systems to which a particular system is linked. The more entropic the structure, the more highly integrated the zone. The following information theoretic formula was used:[57]

$$Z.I. = \frac{-\Sigma p_i \log_2 p_i}{\log_2 N}$$

where p_i is the number of systems to which a system is linked minus 1, divided by the total number of systems linked across all systems, and N is the number of systems.

This measure controls for the number of systems in the zone.

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System openness is operationalized by totalling the number of frequency values which a system has in its one-step and two-step linkages to other systems in its environment. The higher the total frequency value, the higher is the system openness.

System size is determined by the total number of persons within the system. The more people within the system, the larger the system size.

Statistical Procedures and Results

Descriptive statistics for all variables appear in Table 1. Simple correlations among all the variables appear in Table 2. The 37 groups with more than one link to another group in the environment were used in the analysis. All of the independent variables were simultaneously entered into a least squares, linear multiple regression on the dependent variable--the connectedness measure of network complexity. Regression information appears in Table 3. This set of independent variables, whose contributions to explained variance of the dependent variable are adjusted for each other, yields a multiple correlation coefficient of .84 with 70% of the variation in communication network complexity explained. This set of variables drawn from the model explains a very large proportion of the variance in communication network complexity when used together in the regression.

The first proposition (the greater the zone size, the greater the complexity of the internal communication network of the system) is not supported by this analysis. The beta weight for zone size in the regression is .02.

Support is found for proposition 2 with a beta weight for zone integration of -.30. This indicates that as the zone of a system becomes more integrated, its internal communication network complexity decreases. If the assumption made earlier regarding the relationship between

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environmental uncertainty and zone integration is correct, then this indicates some support for the more general proposition that as environmental uncertainty increases, the internal communication network complexity increases.

Proposition 3 is also supported by the data. The beta weight for openness in the regression is .25. This indicates that as the system becomes more open, the system has a more complex internal communication network structure. As with proposition 2, if openness is interpreted to be associated with higher environmental uncertainty, then this is further support for the proposition that as environmental uncertainty increases, the complexity of the internal communication network structure of the system increases.

The fourth proposition is also supported by the data. The beta weight for system size is -.75. This indicates that as the size of the system increases, the internal communication network of the system becomes less complex.

Discussion

The results of the analysis generally support the propositions derived from the model. All but the relationship involving zone size are found to have considerably large beta weights. When all of the independent variables' contributions to explained variance are accounted for, the total amount of explained variation in communication network complexity is very substantial. This preliminary evidence suggests that the model has a potentially high degree of predictive validity and explanatory power.

However, causality questions are not answerable by the analysis procedures which we used. The gathering of evidence for causal sequencing will be of high priority in future research. This is a major shortcoming of the research we report here.

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With respect to generalizability, the data used for the analysis were not collected from a representative sample of groups from across the population of complex organizations. The respondents constitute a census of one large division of an organization. The basis for generalizability is then rather limited. Future research would attempt to gather evidence for these relationships in different kinds of organizations. This is an especially salient point since the main thrust of our model is that different environments have different effects on organizations with different technologies. Attempts should be made to test the model using large organizations as the unit of analysis, in addition to more feasible research which uses smaller subsystems. On the whole, our results would seem to encourage these further explorations.

An important asset of this research is that it uses naturally occurring groups in an on-going, complex social system. Most research on group processes has traditionally been conducted in laboratory settings.[58] Hence, the generalizability of the experimental research is highly questionable.[59] The network analysis procedures we have used appear to be valuable for defining groups in natural settings with standard formalized criteria. This technique can be an important tool for the testing of theoretic propositions that to this point could only be tested in the lab.[60]

Conclusion

In this paper we have developed a preliminary information processing model with application to large social systems. The environmental influences upon organizational processes are of primary importance in the context of this model. In developing the assumptions and propositions of the model we have reviewed the literature on the relationships among environmental

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uncertainty, inter-organizational communication, technology, and communication network structure.

Some propositions derived from the model are tested using subsystems in a larger system as the units of analysis. Communication network analysis is used to define these subsystems. The results generally confirm the propositions, suggesting that further work along these lines is justified.

NOTES

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1. Special thanks to Dr. Richard V. Farace, Jennifer Shelby, and Tim Roth for valuable assistance in various stages of the development of this paper.

2. Some examples of "classical" theories are those of Weber, Taylor, Urwick; some examples of "neo-classical" theories are those of Blau and Simon; some examples of "human relations" theories are those of Roethlisberger and Dickson, Blake and Mouton, and Herzberg.

3. See Fiedler (1958) for an example of a contingency theory of leadership in groups.

4. See Buckley (1968) for an anthology of various articles regarding systems, and Miller (1972), who discusses the organization as a living system.

5. Duncan (1972) distinguishes between the external and internal environment of organizations.

6. For a more extensive discussion of this notion see Weick (1969); Berlo (1967) also provides some interesting insights along these lines.

7. Woelfel (1973) describes this approach to representing cognitive and social processes in which metric multidimensional scaling is used.

8. Shannon and Weaver (1949) develop the formula for calculating entropy: $H = -\Sigma p_i \log_2 p_i$; where p_i is the relative probability of occurrence of each alternative. The operation is repeated for each alternative.

9. See Knight (1921).

10. Lawrence and Lorsch (1967), Terryberry (1968), Duncan (1972), Tosi, Aldag and Storey (1972).

11. Duncan (1972).

12. See Danowski (1974c) for an application of this conception in measuring media channel use entropy with information theory.

13. See Berlo (1970) for a useful definition of communication in terms consistent with a "systems theory" perspective.

14. The work of Emery and Trist (1965), Thompson (1967), Terryberry (1968), and Duncan (1972) suggest two major dimensions to environmental uncertainty: simple-complex, and static-dynamic. This is an interesting analogy to the novelty and complexity dimensions of stimuli developed in psychology (Berlyne, D.E., Conflict, arousal, and curiosity. New York: McGraw-Hill, 1968). Garner (1962) develops a series of multidimensional information theoretic measures which may have useful applications in the organizational environment area.

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15. We are treating this relationship from the perspective that socialization is the primary independent variable. However, it is reasonable to assume that the nature of existing environmental projections will in part determine subsequent socialization. Therefore, in more precise terms, the relationship is mutually reciprocal.

16. See Berlo (1970).

17. See Miller (1965), who explicates a number of cross-level systems hypotheses.

18. See Asimov (1969) for a brief, but informative review of thermodynamics. Katzman (1970) explicates the relationship between thermodynamics and communication processes.

19. Warren (1967) and Turk (1970, 1973) take a "network view" in describing these phenomena. Etzioni (1960) also calls attention to this focus. Clark (1965) proposes that these relationships be examined among organizations in education contexts. Levine and White (1961) and Hasenfeld (1972) develop a perspective on inter-organizational relations from an exchange theory paradigm.

20. Warren (1967) focusses on inter-organizational relations in terms of consensus. Levine and White (1961) and Thompson (1967) explicate the notion of organizational domain in considerable detail.

21. Cushman and Whiting (1972) develop a theoretic perspective on human communication from a consensus approach and explicate fully the notions of 'rules' and its implications.

22. Turk (1973) approaches inter-organizational relations through a discussion of inter-organizational conflict and its relationship to consensus. Coleman (1957) and Stinchcombe (1965) deal with the concept of organizational density and the development of consensus. It can be inferred from these works that greater environmental uncertainty will lead to greater inter-organizational communication network formation and hence, greater consensus.

23. See Barnes (1972) for an extended conceptual treatment of the concept of zone and its various uses.

24. System openness tends to be defined with regard to the total amount of information which a system exchanges with its environment. As such, it is not structurally defined through linkage patterns, but defined through the message volume passing across the system boundary. See Katzman (1970) for a discussion of openness and its relationship to system structure.

25. This variable is discussed in the context of friendship networks and mass media behaviors in Danowski (1974a).

26. Some interesting analogies can be developed from the research on individual human information processing. The research generally shows a U-shaped relationship between information input load and output efficiency, as well as a U-shaped preference for uncertainty (See Schroder, Streufert, and Driver, 1967).

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27. Veblen (1904).

28. Thompson (1967) develops this notion in detail, conceptualizing three kinds of technology: long-linked, mediating, and intensive. Perrow (1967) proposes that technology be the primary defining characteristic for the comparative analysis of organizations.

29. Woodward (1965), Harvey (1968), Pugh, et al. (1968), Hage and Aiken (1969), Mohr (1971), Aldrich (1972), and Pfeffer (1973).

30. Woodward (1965).

31. Litwak distinguishes between uniform and non-uniform technology. (Litwak, E. "Models of bureaucracy which permit conflict," American Sociological Review, 1961, 67, 177-184). Harvey (1968) discusses technology in terms of variability and product change. Hage and Aiken measure the degree to which tasks are routine. (Hage, J. and M. Aiken. "Routine technology, social structure and organizational goals," Administrative Science Quarterly, 1969, 14, 366-377). Mohr (1971) discusses technology in terms of uniformity, complexity, and analyzability. Pugh, et al. (1968) define 'rigidity of task operations' through a factor analysis of a large number of task variables.

32. Thompson (1967).

33. Miller (1964) discusses information overload at the individual level of analysis. Drabeck and Haas (1969) provide experimental evidence for this proposition.

34. Cadwallader (1959) develops a cybernetic analysis of change in complex organizations which has relevance here.

35. Miller (1971) develops a detailed explication of various transduction -- or information processes -- in groups.

36. Miller (1964) discusses irrational methods of coping with information overload.

37. This may be a potentially more theoretically useful view of organization change than the type discussed by Bennis (1969). Terryberry (1968) conceptualizes organizational change as increasingly more "externally induced". However, this distinction appears arbitrary, depending upon the point of focus.

38. Woelfel (1973) discusses conceptual domain from a Newtonian Mechanics perspective, employing such concepts as inertial mass and message force to explain conceptual change over time.

39. Dill (1958), Simpson and Gulley (1962), Lawrence and Lorsch (1967), Conrath (1967), Negandhi and Reimann (1973), and Duncan (1973). This evidence also provides support for proposition 15.

40. Goodman (1973) explicates this construct, marshalling evidence to support the propositions which follow in the text. Lawrence and Lorsch (1967) find that an environmental increases, length of time horizon increases.

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41. Although perceived or anticipated control will be of major importance, more actualized control at a single point in time may be critical in this process. This may derive from powerful situational factors.

42. Simon (1957) is noted for an emphasis on organizational rationality, as are most of the neo-classical theorists of organizations.

43. Terryberry (1968) discusses adaptation and environment in considerable detail.

44. Blau and Scott (1962), for example.

45. It is proposed that increased size leads to more formalized structures.

46. Litwak and Hylton (1961) focus on conflict as a basis for understanding inter-organizational relationships. Turk (1973) also discusses these processes from a conflict perspective. Pfeffer (1972) discusses organizational merger as a function of resource exchange patterns. This has relevance to proposition 14.

47. See Farace and Danowski (1973) for a explication of some basic network analysis concepts, procedures and applications.

48. Social psychology has tended to define strengths of relationships as a function of affect or liking. However, these psychological variables have been found to be a function of the more sociological variable of 'frequency of communication'.

49. A more complex network can be conceptualized as one in which the uncertainty of predicting specific message paths through the network is high.

50. Lawrence and Lorsch (1967) discuss differentiation and integration in detail.

51. Katzman (1970).

52. Schroder, Streufert, and Driver (1967).

53. Woodward (1965), Harvey (1968), Pugh, et al. (1968), Hage and Aiken (1969), Mohr (1971), and Aldrich (1972).

54. Some of these propositions are deduced from others in the model. No direction is specified, since some are indirectly related and others are mutually reciprocal. Further, only associational statistical analysis (multiple regression) is used.

55. See Richards (1971) and Richards, Farace, and Danowski (1973) for a description of the algorithm and program characteristics.

56. This measure has also been used in an analysis of the communication network in a large agency in the Pentagon (see Berlo, et al. "An analysis of the communication structure of the Office of Civil Defense." Technical report, Department of Communication, Michigan State University, 1972).

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57. Berlo, et al. (1972) and Monge describe and use a similar metric to quantify intra-group structure. (See Monge, P. R. "The evolution of communication structure." Unpublished manuscript, Department of Communication, Michigan State University, 1971). In this research we develop an application to inter-group structure.

58. See Collins and Raven (1969) for a review of empirical research on groups.

59. Guetzkow (1965) discusses the problems of poor generalizability of lab research to organizations more fully.

60. See Seashore (1964) for a discussion of the conduct of field experiments in organizations.

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Figure 1. Major Components of the Model

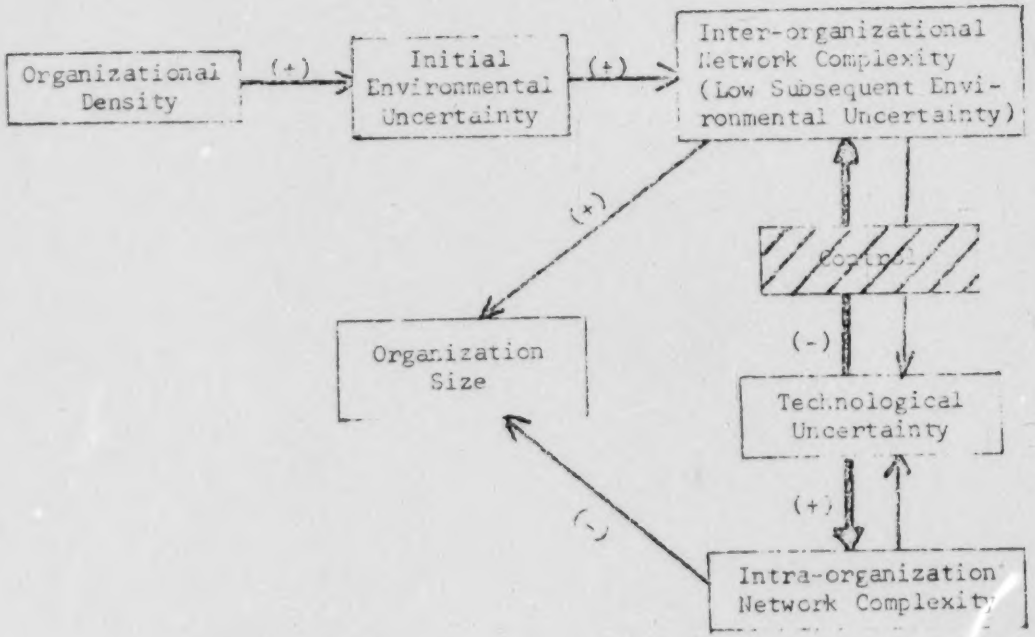

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Table 1

Descriptive Statistics

Variable	Minimum	Maximum	Mean	S.D.
Connectedness	0.13	0.83	0.42	0.16
Zone Size	.00	7.00	2.73	1.17
Zone Integration	0.00	1.00	0.45	0.46
Openness	21.00	534.00	156.70	139.20
System Size	3.00	16.00	8.43	3.48

(N = 37)

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Table 2

Simple Correlations

	1	2	3	4	5
1. Connectedness	1.00				
2. Zone Size	.00	1.00			
3. Zone Integration	- .13	.07	1.00		
4. Openness	.39	.38	.15	1.00	
5. System Size	- .75	.12	- .17	- .22	1.00

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Table 3

Multiple Regression Information

Dependent Variable: Connectedness

A. Analysis of Variance for Overall Regression

	Sum of Squares	d.f.	Mean Square	F	sig.
Regression (about mean)	.63	4	.16	18.5	<.0005
Error	.27	32	.008		
Total (about mean)	.89	36			

B. Multiple Correlation Coefficients

R^2	R	R Bar^2	R Bar	Standard Error
.70	.84	.66	.81	.09

C. Independent Variables

Variable	Beta Weight	S.E.	sig.
Zone Size	.02	.11	.842
Zone Integration	-.30	.10	.005
Openness	.25	.11	.028
System Size	-.75	.10	<.0005